Design of Wide band Microstrip Helical Antenna for Space Applications

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***Abstract*— This paper proposes a wideband microstrip helical antenna for space applications. The frequency band considered is 8-12 GHz. The return loss, far field radiation and peak gain characteristics of this antenna are presented. The numerical analysis and optimization are performed with the HFSS (commercial software), which is based on the finite element method.**

Keywords- helical microstrip antenna; wideband antenna„; HFSS.

I. INTRODUCTION

Helical antennas are popular for space applications due to their broadband nature, high gain, and circular polarization. Conventional helical antenna design is accomplished through the use of multiple design graphs, empirically developed gain equations, and extensive hand-tuning. These graphs and equations have been developed over the five decades since the realization of the first helical antenna by Kraus in 1946 [1]. A few modifications have been made to the original helical antenna to improve its radiation characteristics [2-3]. However, the frequency bandwidth is not wide enough.

In this paper, a wideband microstrip helix antenna is designed and optimized for a LEO satellite in X-band (8-12 GHz). The main goal of this new design is to exhibits a wide bandwidth by introducing a dielectric cylinder with low relative permittivity (figure.1). For the antenna analysis and optimization, we have used HFSS (high Frequency Structure simulator), the powerful electromagnetic field simulation software which uses FDTD [4]. We applied the Genetic algorithm (GA) and Quasi-Newton (QN) optimization methods to design the antenna. The GA method is able to optimize different natural variables, is the most versatile approach. It can find global optimal solution. Applications of genetic algorithms are reported in recent years [5-9]. The numerical results show that the GA is more efficient than the QN. Results regarding antenna parameters such as return loss, radiation pattern and gain will be presented.

II. ANTENNA STRUCTURE AND DESIGN GUIDELINES

Figure 1 shows the geometry of microstrip helical antenna fed by a 50-Ohm coaxial probe. The antenna consists of one hollow dielectric cylinder with a relative permittivity equal to 2.1 and outer radius equal to 5.87mm. The helix radius, conducting core radius and the ground plane radius are set equal to 6.2mm, 0.35mm and 11.3mm. Then, the rest parameters of the antenna, the height (h), inner radius (r) of dielectric cylinder, pitch Length (p) and number of turns (N) are optimized so that the return loss of the antenna becomes smaller that 15 dB over the x-band frequency. For this purpose, the optimization are performed using the optimetric tools (Genetic algorithm and quasi–Newton optimization methods) available in HFSS [4].

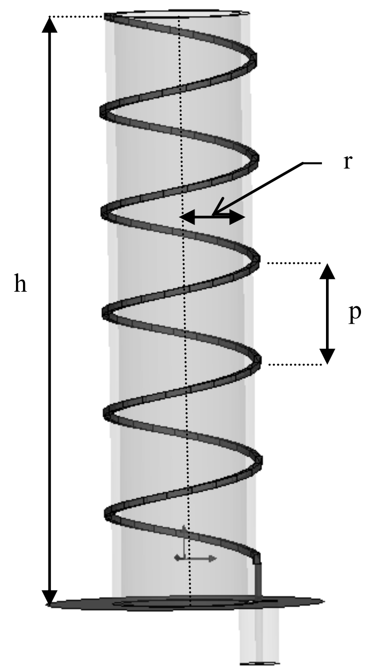

Fig.1. Geometry of the proposed antenna

III. GENETIC ALGORITHMS OVERVIEW

A. Introduction

The concept of the Genetic Algorithm, first formalized by Holland and extended to functional optimization by De Jong [5], involves the use of optimization search strategies patterned after the Darwinian notion of natural selection and evolution. During a GA optimization, a

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set of trial solutions is chosen and evolves toward an optimal solution under the selective pressure of the object function.

In general, a GA optimizer must be able to perform five basic tasks

1) encode the solution parameters in the form of chromosomes,
2) initialize a starting population,
3) evaluate and assign fitness values to individuals in the population,
4) perform reproduction through the fitness weighted selection of individuals from the population, and
5) perform recombination and mutation to produce members of the next generation.

This algorithm is represented in Figure 2.

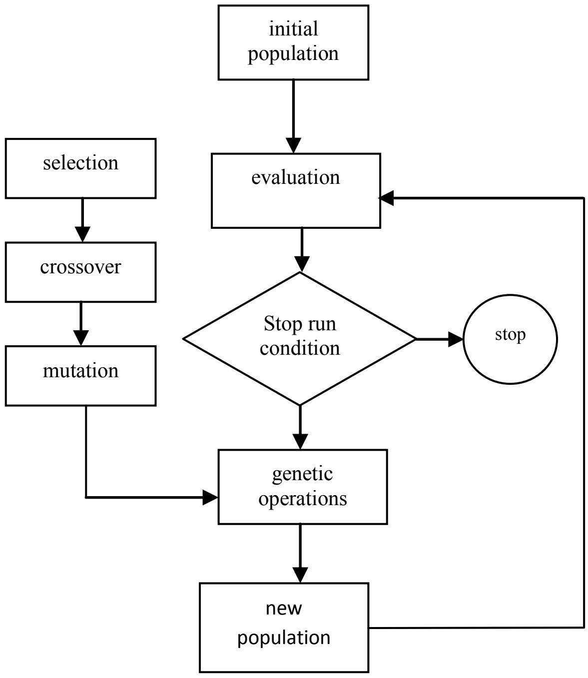

Fig.2. Genetic algorihm

B. *Selection, reproduction*

Each of the individuals is selected by its fitness value. Reproduction consists in duplicating each individual in ralation to the average of the performances for all the chromosomes of population. Then individuals which give the best results have a good probability to be selected for the next generation.

C. *Crossover*

After the reproduction step, a crossover allows a generation of new individuals. The crossover step consists to cut two chromosomes, named parents, on a random place, then the end of these two individuals string is reversed and two chromosomes are created and named children.

D. *Mutation*

Mutation consists to modify in a random way and with a small probability (0.01-0.1) the bit value of a chromosome. In other words, a “1” becomes a “0” and a “0” becomes a “1”.

IV. QUASI-NEWTON METHOD

Many methods for solving minimization problems are variants of Newton method, which requires the specification of the Hessian matrix of second derivatives. Quasi-Newton methods are intended for the situation where the Hessian is expensive or difficult to calculate. Quasi-Newton methods use only first derivatives to build an approximate Hessian over a number of iterations [10]. This approximation is updated each iteration by a matrix of low rank. The general algorithmic structure is as follows:

(1) Set $d^k = -(H^k)^{-1}\nabla f(x^k)$
(2) Determine $x^{k+1} = x^k + \alpha_k d^k$ by a step size strategy.
(3) Use x^k, x^{k+1} and H^k to update H^k to H^{k+1}.

For the initial matrix H^0 choose a (symmetric) positive definite matrix. A standard choice is given by $H^0 = I$, but sometimes better scaling might be necessary. The benefits of quasi- Newton methods are (amongst others):

- Only first order derivatives are required.
- H^k is always positive definite such that d^k is a descent direction for *f (function to optimize)* at x^k and our line search framework is applicable.

V. NUMERICAL RESULTS

The optimum parameters obtained by the aforementioned procedures are given in the following table:

TABLE I OPTIMUM ANTENNA PARAMETERS

Antenna parameters \ Optimization method	Quasi-Newton	Genetic Algorithm
height (h)	46mm	44.92mm
Inner radius (r)	5.27mm	5.10mm
pitch length (p)	7.60mm	8.02mm
number of turns (N)	5	5.40

The genetic characteristics are as follows: coding of the parameters on 16 bits, number of chromosomes by population: 100, number of generation: 100, probability of cross-over: 0.8 and probability of mutation: 0.01.

Figure.3 shows the return loss of the antenna with the optimal set of parameters. From this figure, the antenna proposed in this paper optimized by genetic algorithm satisfies the requirement as wideband antenna; return loss of 15dB is achieved in the 8–12 GHz band. The results were fairly similar to what was expected.

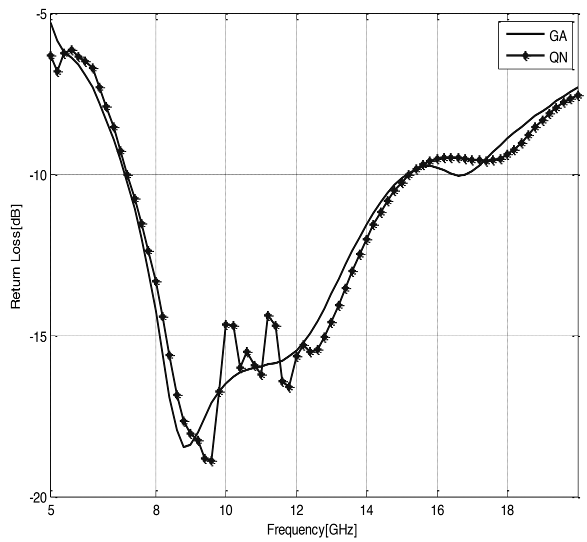

Fig.3. Return loss of the antenna

The computed radiation patterns of the proposed antenna optimized by genetic algorithm in E and H-plane at the operating frequency, 9 GHz, are shown in Fig. 4. It can be seen that the radiation patterns is better at the operating frequency 9GHz. These clearly met the specifications of the antenna.

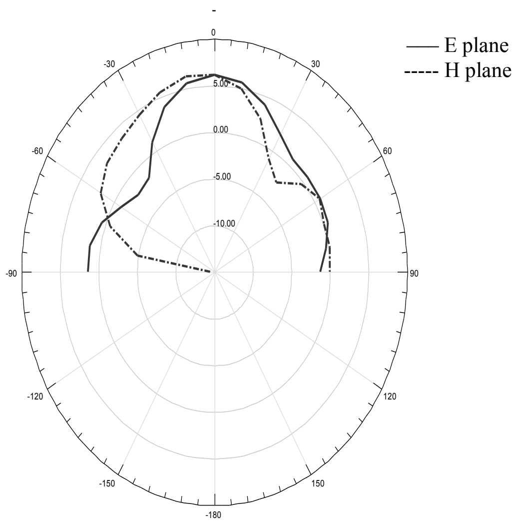

Fig.4. Radiation patterns in the E and H-plane, for the proposed antenna at 9 GHz.

Figure 5. Shows the peak gain of the antenna calculated by HFSS. From this figure, the antenna gain within thin X-band is found to range from approximately 3.6 to 8 dB. It can be concluded that the gain variation is less than 3 dB over the entire operating frequency range from 8 to 12 GHz.

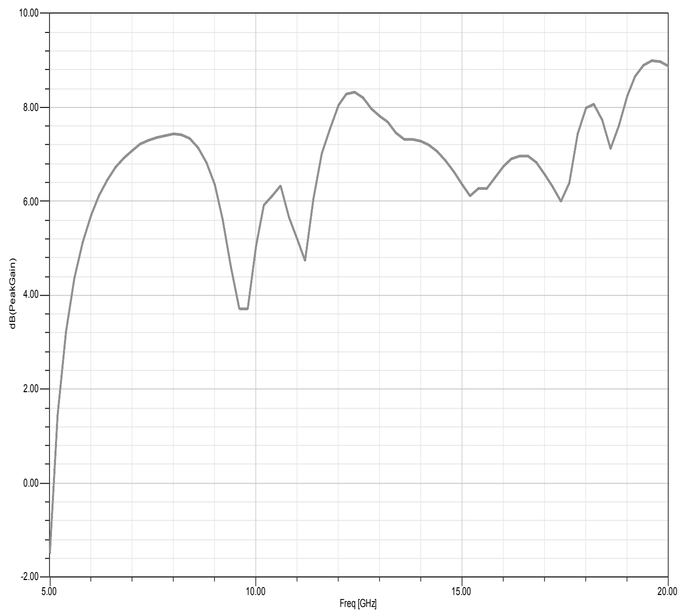

Fig.5. Peak antenna gain

VI. CONCLUSION

In this paper, a wideband microstrip helical antenna has been proposed for space applications. The bandwidth for 15 dB return loss has been achieved for the frequency band between 8 GHz and 12 GHz. In this frequency band, the peak gain approximately 3.6 to 8 dB has been observed, together with broad-side radiation patterns in both E and H planes.

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